AMENDMENTS TO THE SPECIFICATION

[0033] Figures 1 and 2 show a typical bending machine that can be configured to employ a bend arm having a clamping assembly in accordance with embodiments of the invention. Figure 1 shows a tube bending machine 100 having a bend arm ~~404~~ 410 configured with a clamping assembly 400, as will be further described below with reference to Figures 4 through 15. The bender 100 includes a bed 110 that supports a carriage assembly 120. A rotatable chuck 130 couples to the carriage assembly 120 and is configured to grip a workpiece such as a tube 340.

[0034] In operation, the carriage assembly 120 and chuck 130 cooperate to translate and rotate the workpiece 340 to place it at a desired bending location in a bending zone ("bend head"), which comprises a bend die 338 and a clamp die 312. The workpiece 340 is gripped by the bend die 338 and clamp die 312 as the bend arm 404 is rotated about an axis 401 of the bend die 338. An actuator 140 suitably coupled (not shown) to the bend arm ~~404~~ 410 rotates the bend arm ~~404~~ 410 about the axis 401. A restraint block 150 restrains the workpiece 340 at point between the bend head and the chuck 130. In the embodiment shown, the bender 100 has bent a portion of the workpiece 340 through a 90 degree angle.

[0035] To perform a subsequent bend on the same workpiece 340, the clamp assembly 400 retracts and lowers a bend arm slider 402 relative to the bend die 338 (see Figures 9-11). Since the clamp die 312 is coupled to the slider 402, the clamp die 312 also retracts and falls away from the workpiece 340 and the bend die 338. The actuator 140 returns the bend arm ~~404~~ 410 to the starting position shown in Figure 1. Next, the carriage 120 and chuck 130 position the workpiece 340 at the new bend location. Then the clamping assembly raises and extends the slider 402 to engage the clamp die 312 against the workpiece 340. The actuator 140 rotates the bend arm ~~404~~ 410, as previously described, to produce the new bend on the workpiece ~~440~~ 340.

[0043] Figure ~~3B~~ 3C is a diagram of another exemplary arrangement for obtaining the force multiplication provided by the lever 330 of Figure 3A. In Figure 3B, the force multiplication is obtained by pivotally coupling a single-arm lever 330B to a support and pivot member 336B characterized by an axis 335B. A pivot member 328B having an axis 332B can be fixedly coupled to the lever 330B. The drive link 322 (not shown in Figure 3B) pivotally couples to the pivot member 328B. When the actuator 326 pulls the member 337B at the lever second

end 330B'', the drive link 322 rotates clockwise about the axis 335B, thereby pushing the drive link first end 322' to press against the toggle link 320. This configuration corresponds to a second class lever (*i.e.*, where the load is between the fulcrum and the effort). In this case, the effort arm is the distance D1' between the axis 335B and the line of action of the force provided by the actuator 326 at the member 337B. The load arm is the distance D2' between the axis 335B and the axis 332B. The force multiplication is the ratio of the lever arm to the load arm, namely D1':D2'.

[0052] A retaining member 427 keeps the push rod 426 pressed against one end of the guide slot 424 during the raising and extending of the slider 402. The interaction between the push rod 426 and the drive link second end 422'' results in the raising of the toggle link 420. However, once the slider 402 is raised and extended into engagement with the workpiece 430, the motor 428 and lead screw mechanism 430 overcome the resistance of the retaining member 427 and pull the push rod 426 into engagement with the first arm 440' of the force multiplier arm 440. Through this coupling, the motor 428 applies a controlled and variable force against the workpiece 340, as the force is transmitted to the workpiece 340 via the drive link 422, toggle link 420, lever 414, slider 402 and clamp die 312. In one embodiment, the motor 428 is an electric servo motor that can be programmed to provide a certain level of torque to the lead screw mechanism 430. Once programmed, the motor 428 will pull the push rod 426 against the force multiplier arm ~~340~~ 440 to maintain the desired torque level.

[0053] That is, the motor 428 pulls the push rod 426 against the first end ~~440''~~ 440' of the force multiplier arm 440 causing the bearing member 434 to pivot clockwise about the axis 437 (see Figure 13). Since the pivot member 432 is fixedly attached to the bearing member 434 through the connecting member 435, the pivoting of the bearing member 434 about the axis 437 results in the rotation of the pivot member 432 about the axis 437. The rotation of the pivot member 432 causes the drive link 422 to push against the toggle link 420, which in turn presses against the lever second end 414''. The lever 414 thus is forced into a further clockwise movement about the axis 418, which results in the lever 414 pushing the slider 402 and clamp die 312 with high force against the workpiece 340.

[0057] In one embodiment, the connecting member 435 and force multiplier arm 440 are configured to couple to the bearing member 434 such that the force multiplier arm 440 is

positioned at a slight angle, as shown in Figure 12B, when the slider 402 is at the top of the movement. This position of the force multiplier arm 440 allows for continued application of a controlled force to a workpiece 340 in situations where, for example, the clamp die 312 and bend die 338 compress the workpiece ~~440~~ 340. As the workpiece 340 is compressed, the push rod 426 can continue to press against the force multiplier arm 440, thereby causing the force multiplier arm 440 to continue pivoting about the axis 437. That is, one of the functions of the guide slot 424 and the angled position of the force multiplier arm 440 is to provide for a space and for movement such that the force multiplier arm 440 can effectively apply a constant force to a workpiece 340 even in situations where there is compression or slippage at the workpiece 340.

[0065] In one embodiment, the force multiplier arm 440 comprises a first arm 440' coupled to a second arm 440''. The first arm 440' is about 3.5 inches long, 1.25 inches wide and 0.4 inches thick. One end of the first arm 440' is configured with a rectangular notch for engagement to the connecting member ~~437~~ 435. The other end of the first arm 440' is configured with a space for receiving the push rod 426. The second arm 440'' is 3.5 long, 1-inch wide and 0.4 inches thick. One end of the second arm 440'' is configured with a rectangular notch for engagement to the connecting member ~~437~~ 435. The other end of the second arm 440'' is configured with a space for receiving the push rod 426.

[0066] When coupled together, the first arm 440' and the second arm 440'' clamp onto the connecting member ~~437~~ 435 and provide the structure by which the push rod 426 can transfer the force from the motor 428 and lead screw mechanism 430 to the bearing member 434, which then transmits the force to the drive link 422 via the connecting member ~~437~~ 435 and the pivot member 432.

In the Abstract:

A clamping assembly for use with a bend arm of a tube bending machine ~~is provided~~. The ~~clamping~~ assembly comprises a force multiplier linkage that applies a controlled and variable force to a workpiece. In one embodiment, the force multiplier linkage comprises a bearing member pivoted by an actuator acting on one end of a force multiplier arm that is attached to the bearing member. ~~The pivot axis of the bearing member and the line of action of~~

~~the actuator define a lever arm distance D1. In one embodiment, a~~ A pivot member supporting a drive link is fixedly attached to the bearing member at a location offset from the bearing member's pivot axis ~~of the bearing member~~. The drive link ~~is configured to~~ pivots about the pivot member axis so that in cooperation with additional links it moves a bend arm slider. The drive link ~~is further configured to~~ also pivots about the ~~axis of the~~ bearing member axis. ~~The axis of the bearing member and the pivot member axis define a load arm distance D2.~~ As the bearing member is pivoted about its axis by the force multiplier arm, the drive link also pivots about ~~the axis of~~ the bearing member's axis providing the required force for application to the workpiece. ~~In one embodiment, the force multiplication is substantially equal to the ratio of D1 to D2.~~